NACA

RESEARCH MEMORANDUM

EFFECTS OF THE SPANWISE, CHORDWISE, AND VERTICAL LOCATION OF AN EXTERNAL STORE ON THE AERODYNAMIC CHARACTERISTICS OF A 60° DELTA WING AT MACH NUMBERS OF 1.41, 1.62, AND 1.96

By Carl R. Jacobsen

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NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS

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SUMMARY

An investigation has been made in the Langley 9- by 12-inch supersonic blowdown tunnel to determine the effects of external store location on the lift, drag, and pitching-moment characteristics of a 60° delta wing at Mach numbers of 1.41, 1.62, and 1.96. The vertical and chordwise location of a Douglas Aircraft Company, Inc., store of fineness ratio 8.58 was systematically varied at 40 and 60 percent of the wing semispan. Brief comparative tests were made to determine the effects of changing the sweep of the strut attaching the store to the wing, and of changing the chordwise location of the swept strut. The Reynolds number of the investigation based on the wing mean aerodynamic chord ranged from 2.4×10^6 to 2.8×10^6.

INTRODUCTION

External stores have been used to advantage in carrying fuel and ordnance on aircraft and a fairly large amount of information is available concerning their aerodynamic influence on wing characteristics at subsonic and transonic speeds (for example, see refs. 1 to 8). It is desirable to know whether stores can still be used advantageously at supersonic speeds, but little information is available since the few experimental investigations to date (refs. 9 to 11) have been very limited in scope. Consequently, in order to obtain comprehensive experimental information at supersonic speeds, an exploratory program has been initiated in the Langley 9- by 12-inch supersonic blowdown tunnel to study the effects of stores on the aerodynamic characteristics of several wing configurations. The investigation of the effects of one size of an external store on the aerodynamic characteristics of an unswept wing was reported in reference 12.

This paper contains data obtained with the same external store on a 60° delta wing which had 3-percent-thick airfoil sections. The store had a fineness ratio of 8.58 and a Douglas Aircraft Company, Inc., store shape. The ratio of the store size to the wing area was such that for a wing area of 750 square feet the store would have sufficient volume to contain about 400 gallons of fuel. The store chordwise and vertical location was systematically varied at 40 and 60 percent of the wing semispan at Mach numbers of 1.41, 1.62, and 1.96 and at wing lift coefficients up to 0.60. A brief investigation of strut sweep angle and of strut chordwise location was also made. The test Reynolds number based on the wing mean aerodynamic chord ranged from 2.4×10^6 to 2.8×10^6. The data are presented without analysis to expedite publication.

COEFFICIENTS AND SYMBOLS

C_L lift coefficient, Lift/qS

C_D drag coefficient, Drag/qS

C_m pitching-moment coefficient, $\left(\dfrac{\text{Pitching moment about } 0.25\bar{c}}{qS\bar{c}}\right)$

$\dfrac{dC_m}{dC_L}$ rate of change of pitching-moment coefficient with lift coefficient

ΔC_m increment in wing pitching-moment coefficient caused by addition of external store

ΔC_D increment in drag coefficient due to addition of external store

q free-stream dynamic pressure

S semispan wing area (13.5 square inches)

c wing chord

$\bar{c}$ mean aerodynamic chord

b wing span, twice distance from wing root chord to wing tip

d store diameter

l store length

x chordwise distance from line perpendicular to $\bar{c}$ at the quarter-chord station to store $0.4l$ point

y	spanwise distance from wing root chord to store center line
z	vertical distance from point of maximum thickness on wing lower surface to store center line
α	angle of attack
$\Delta\alpha$	change in angle of attack required to maintain store-off lift coefficient when store is added
R	Reynolds number based on $\bar{c}$

MODELS

The principal dimensions of the semispan delta wing are contained in figure 1. The sections taken parallel to the air stream were NACA 65A003 airfoil sections. The solid wing was fabricated from SAE 4130 heat-treated steel.

External stores having a Douglas Aircraft Company (DAC) store shape of fineness ratio 8.58 were tested at 40 and 60 percent of the wing semispan (fig. 2). The store 40-percent-length point was located on and $0.302\bar{c}$ behind the quarter-chord station of the mean aerodynamic chord and the vertical locations of the stores were varied from 0.5 to 2.0 store diameters below the lower surface of the wing. The center lines of all stores were within 1° of being parallel to the body axis. Each store was molded of plastic and was designed to have a gross volume of approximately 414 gallons for a wing area of 750 square feet.

Brass struts having NACA 65A005.5 airfoil sections and chords equal to $0.366\bar{c}$ were pinned and sweated to the wing lower surface for the purpose of attaching the stores to the wing. Unswept struts were used for that part of the investigation for which the store location was varied. The leading edge of the unswept struts coincided with the wing leading edge for all but the inboard rear store location $\left(\frac{x}{\bar{c}} = -0.302, \ \frac{z}{d} = 0.5\right)$ in which case the nose of the store was behind the wing leading edge. In an attempt to approximate the condition that existed at the wing leading edge for the other store locations, a thin brass sheet was used to fair in the space between a line extending from the wing leading edge to the store nose and the strut leading edge.

Sweptforward struts were used to position the store at one spanwise and chordwise location $\left(\frac{y}{b/2} = 0.60, \ \frac{x}{\bar{c}} = 0\right)$ in order to obtain the effects

[redacted]

of strut sweep and of strut chordwise location (see fig. 2). One swept-forward strut located at the wing leading edge was used to position the store at $\frac{z}{d} = 1.0$ to obtain data comparable to those obtained with the unswept strut. The effects of strut chordwise location were obtained by positioning the store at $\frac{z}{d} = 2.0$ with two swept struts, one with its leading edge intersecting the wing leading edge and the other with its leading edge set back on the wing to the 40-percent chord station.

TUNNEL

The Langley 9- by 12-inch supersonic blowdown tunnel in which the present tests were made uses the compressed air of the Langley 19-foot pressure tunnel. The air enters at an absolute pressure of about $2\frac{1}{3}$ atmospheres and is conditioned to insure condensation-free flow by being passed through a silica gel dryer and then through banks of finned electrical heaters. The criteria for the amount of drying and heating required were obtained from reference 13. Extensive calibration measurements had been made previously with no model in the test section and a summary of these measurements is contained in reference 14. A brief summary of these results is also contained in the following table along with the average dynamic pressure and Reynolds numbers for the present investigation:

Variables \ Average Mach number	1.41	1.62	1.96
Maximum deviation in Mach number	±0.02	±0.01	±0.02
Maximum deviation of static to stagnation pressure, percent	±2.0	±1.3	±2.2
Maximum deviation in stream angle, deg	±0.25	±0.20	±0.20
Average dynamic pressure for these tests, lb/sq in.	12.0	11.4	10.4
Average Reynolds number, R	2.8×10^6	2.6×10^6	2.4×10^6

The test Reynolds number decreased about 4 percent during the course of each run because of the decreasing pressure of the inlet air.

TEST TECHNIQUE

The semispan wing model used in this investigation was cantilevered from a strain-gage balance which mounts flush with the tunnel wall and rotates with the model through the angle-of-attack range. A test body was attached to the wing and loads were measured on the wing-body combination. The test body consisted of a half-body of revolution and a 0.25-inch shim. The half-body of revolution was shimmed away from the tunnel wall to minimize the effects of the tunnel-wall boundary layer on the flow over the body of revolution (ref. 15). A gap of about 0.010 inch was maintained between the test body and tunnel wall (see fig. 1) under a no-load condition. The investigation was made at Mach numbers of 1.41, 1.62, and 1.96 and at wing lift coefficients up to 0.60. There was some indication that at a Mach number of 1.41 the data of the present investigation might have been influenced by the reflection of the model bow wave from the tunnel wall at an angle of attack of 12°.

ACCURACY OF DATA

From a general consideration of the balance-calibration accuracy and the repeatability of data, the accuracy of the force and moment measurements, in terms of coefficients, is believed to be about as follows:

C_L . . . . ±0.005
C_D . . . . ±0.001
C_m . . . . ±0.002

For lift coefficients above 0.50, errors in drag coefficient in excess of ±0.001 could well exist.

RESULTS

Lift, pitching-moment, and drag data are presented herein without analysis for the body alone, for the wing-body combination, and for the wing-body-store combinations. Figure 3 presents the variations of lift, pitching moment, and drag coefficient with angle of attack at Mach numbers of 1.41, 1.62, and 1.96 for the body alone. Figures 4 to 12 present the variations of pitching-moment coefficient, angle of attack, and drag coefficient with lift coefficient for the wing-body-store combinations at the same three Mach numbers. Because these force and moment data include loads on a somewhat arbitrary test body, the data are not directly applicable to configurations including more conventional body arrangements.

From these data of figures 4 to 12 values of $\frac{dC_m}{dC_L}$ and increments of pitching-moment coefficient and angle of attack at zero lift due to the addition of the store have been obtained and are presented in figure 13. It might be pointed out that positive increments in pitching moment at zero lift caused by the store as shown in figure 13 were also obtained in the investigations of references 11 and 12. The variations of the lift-drag ratios with lift coefficient for the various store locations have also been obtained and are presented in figure 14 along with the drag increments caused by the addition of the store. Similar summary plots are presented in figure 15 to show the effects of strut sweep and strut chordwise location. These values of lift-drag ratio are for this particular test arrangement and, as was just pointed out, would not have any direct application to a different arrangement. It is believed, however, that the trends indicated by the data would not be qualitatively affected by the use of a different body configuration.

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Fuselage Coordinates	
Station	Radius
0	0
0.500	0.087
1.000	.166
1.500	.240
2.000	.305
2.500	.361
3.000	.410
3.500	.453
4.000	.480
4.500	.497
5.000	.500
10.000	.500

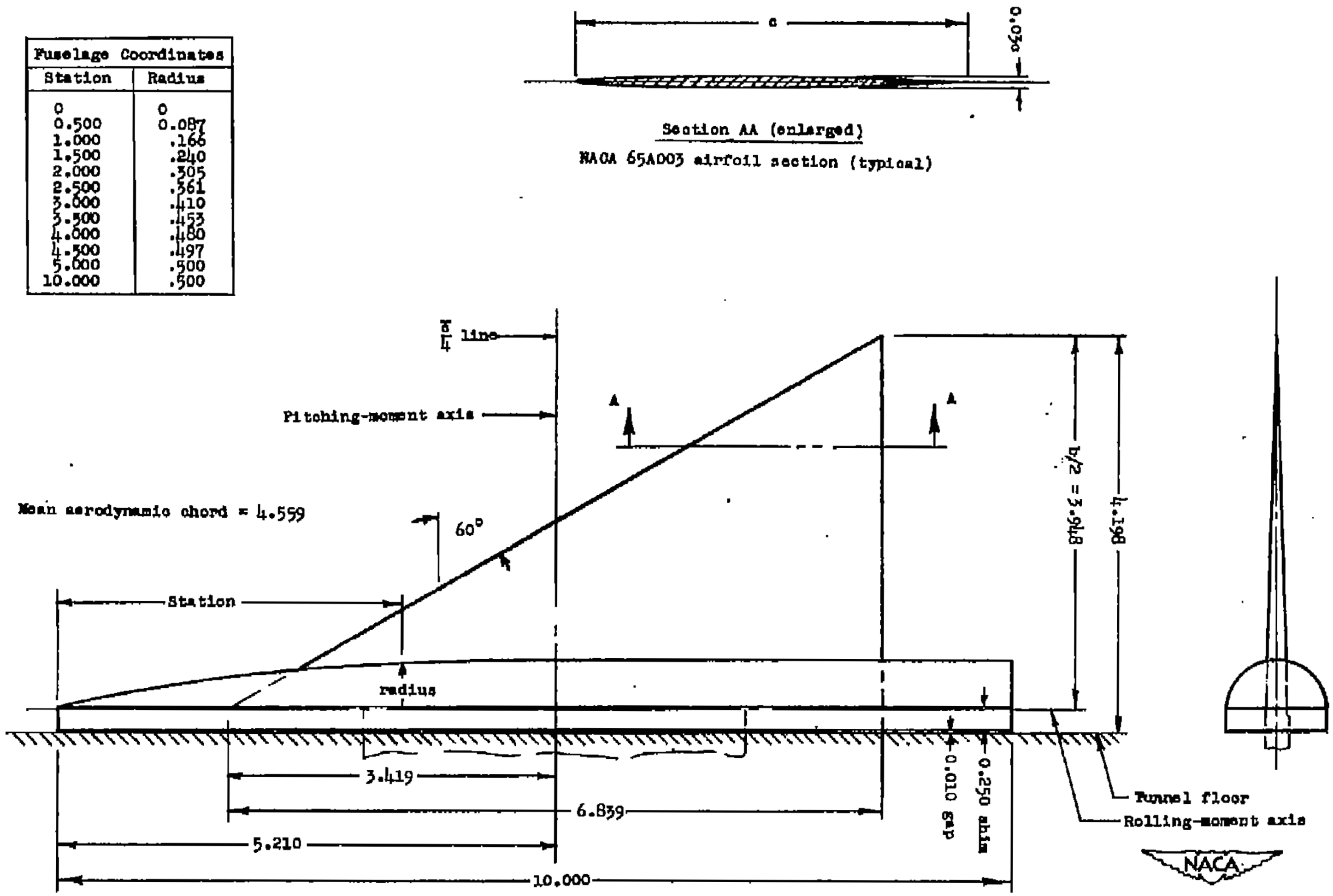
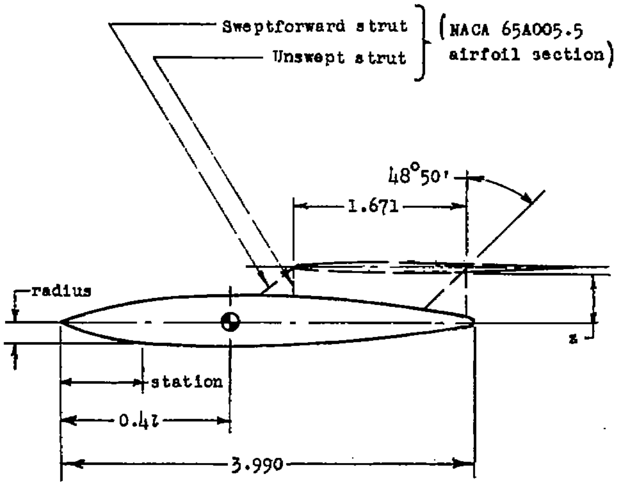


Figure 1.- Details of unswept semispan delta wing. All dimensions in inches.

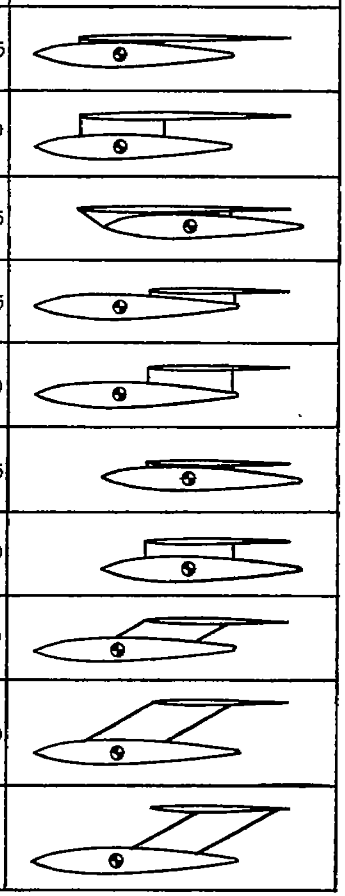


DAC store (typical)

Fineness ratio = 8.58

DAC Store Coordinates	
station	radius
0	0
0.076	0.036
.188	.080
.299	.116
.411	.140
.519	.160
.630	.176
.742	.188
.966	.211
1.185	.227
1.408	.233
1.983	.233
2.206	.229
2.426	.219
2.645	.203
2.873	.184
3.204	.148
3.423	.120
3.647	.088
3.910	.048
3.990	0
T.E.R.	.022

$\frac{y}{b/2}$	$\frac{x}{c}$	$\frac{z}{d}$	Wing-strut-store configuration
0.40	0	0.5	
	0	1.0	
	0.302	0.5	
0.60	0	0.5	
	0	1.0	
	0.302	0.5	
	0.302	1.0	
	0	1.0	
	0	2.0	
	0	2.0	



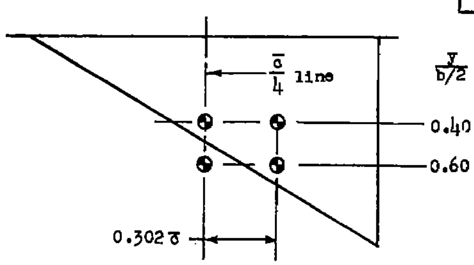


Figure 2.- Details of Douglas Aircraft Company, Inc., store and various locations at which stores were tested. All dimensions in inches.

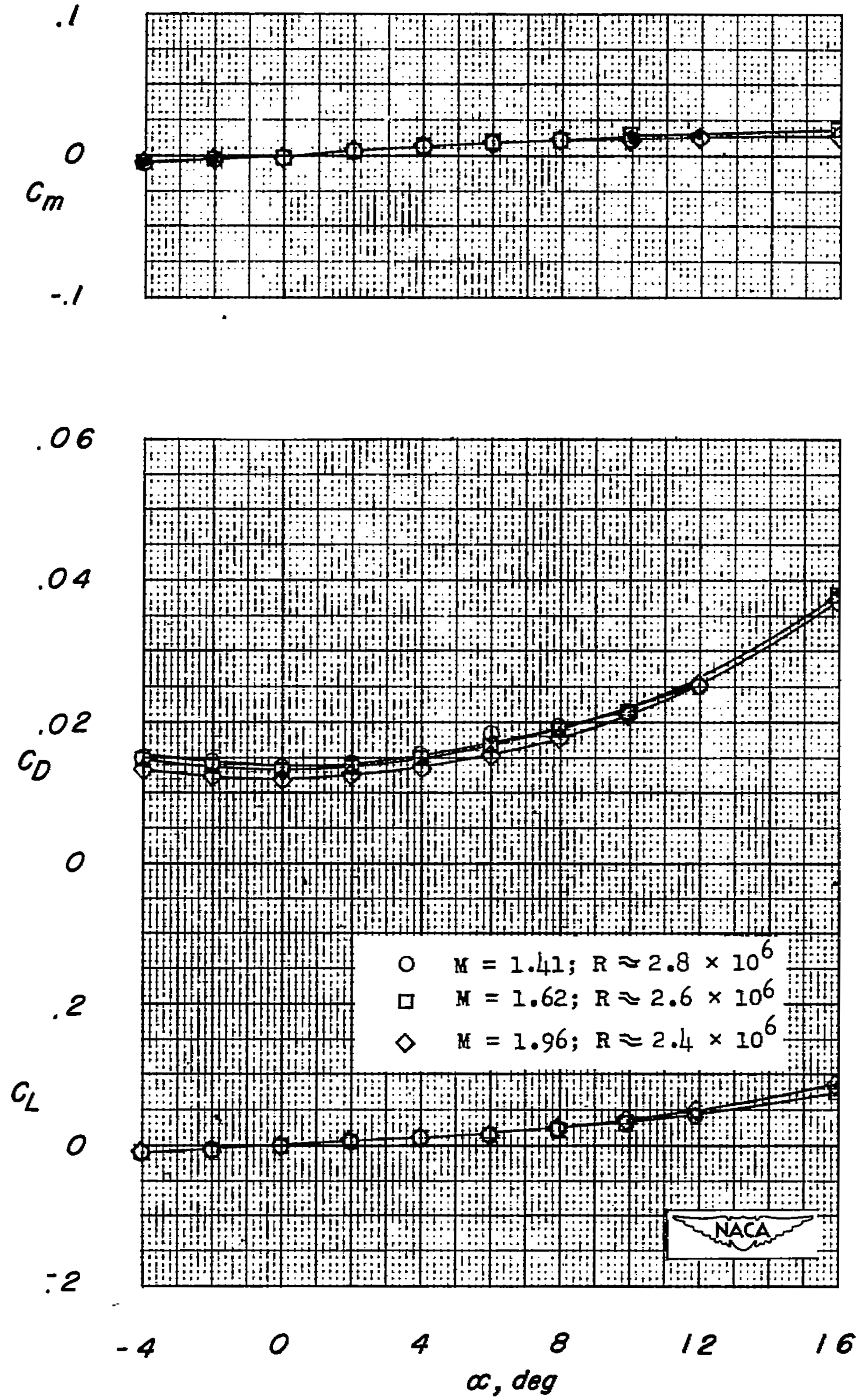
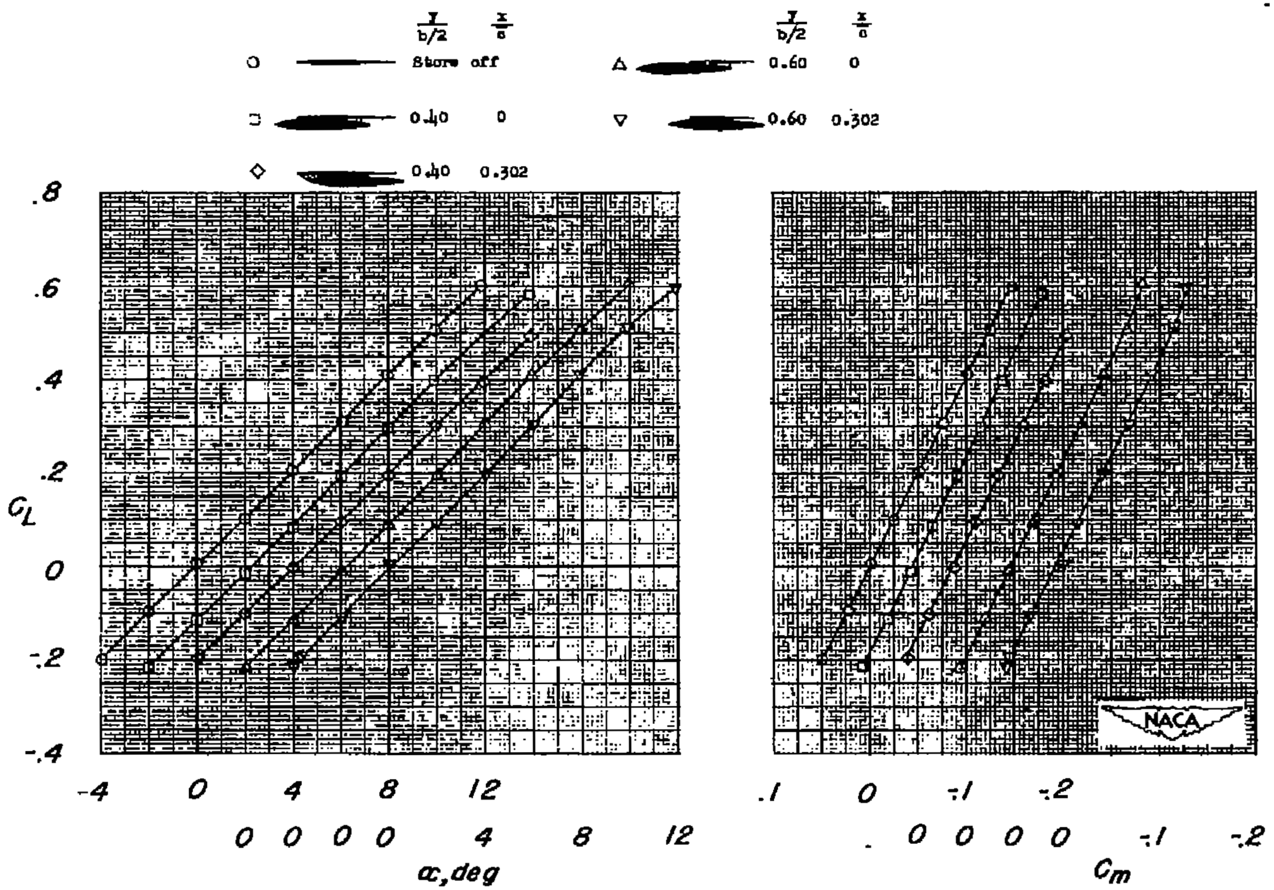


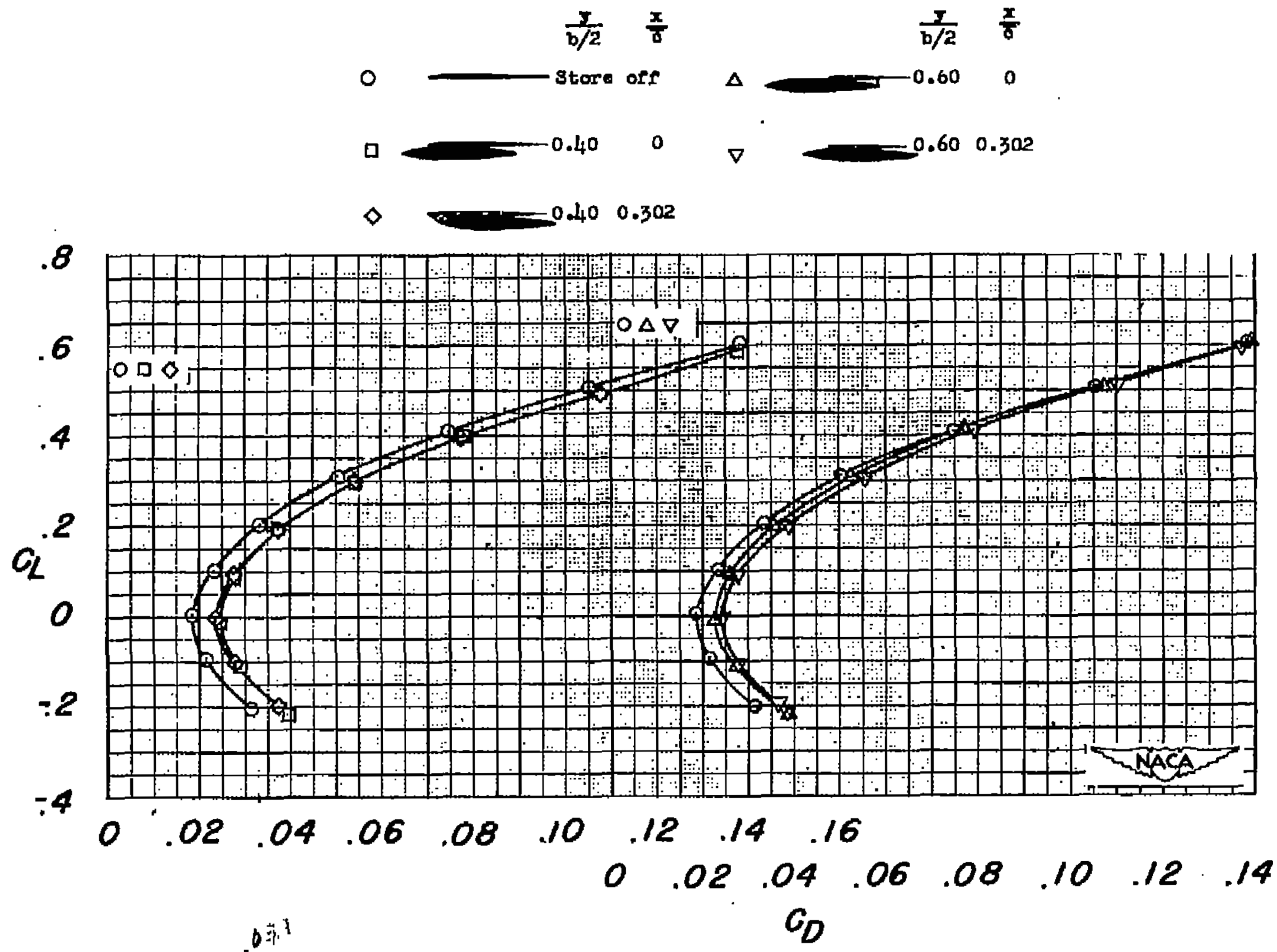
Figure 3.- Aerodynamic characteristics of the test body.



(a) C_L against C_m and α.

Figure 4.- Aerodynamic characteristics of the semispan model with DAC store at various chordwise and spanwise locations. $M = 1.41$; $R \approx 2.8 \times 10^6$; $\frac{z}{d} = 0.5$.

[redacted]



(b) C_L against C_D.

Figure 4.- Concluded.

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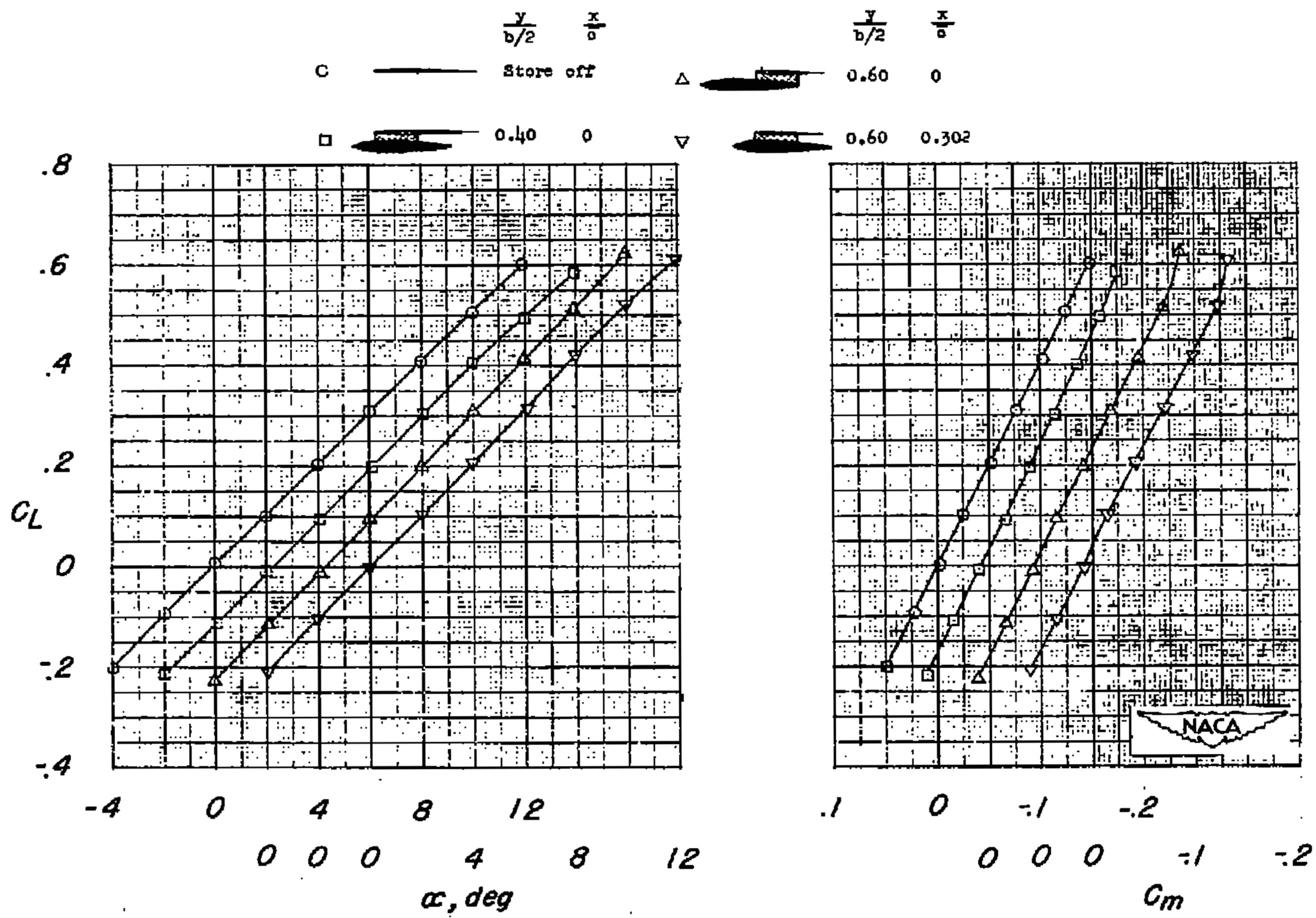
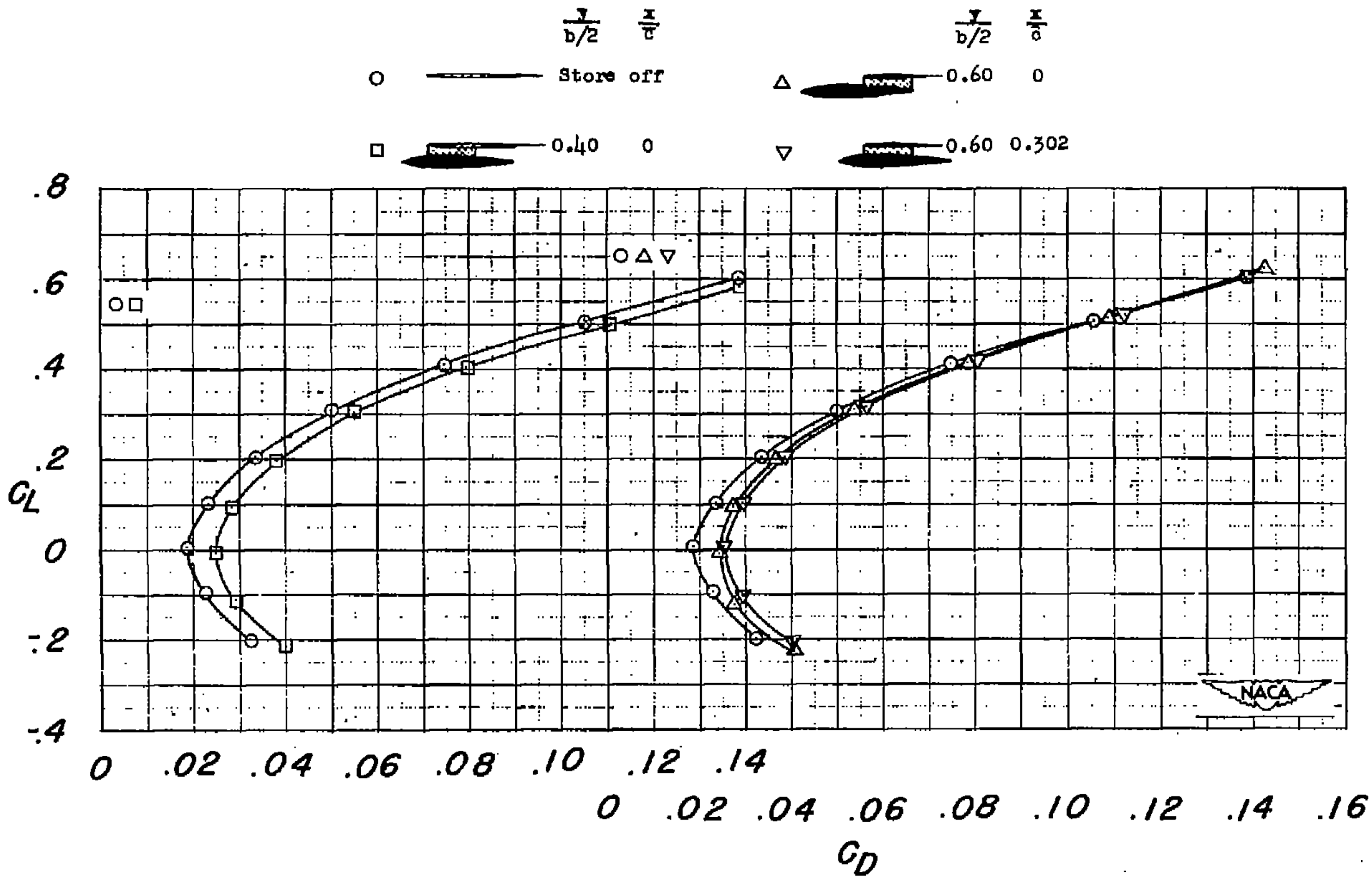


(a) C_L against C_m and α.

Figure 5.- Aerodynamic characteristics of the semispan model with DAC store at various chordwise and spanwise locations. $M = 1.41$; $R \approx 2.8 \times 10^6$; $\frac{z}{d} = 1.0$.

[redacted]



(b) C_L against C_D.

Figure 5.- Concluded.

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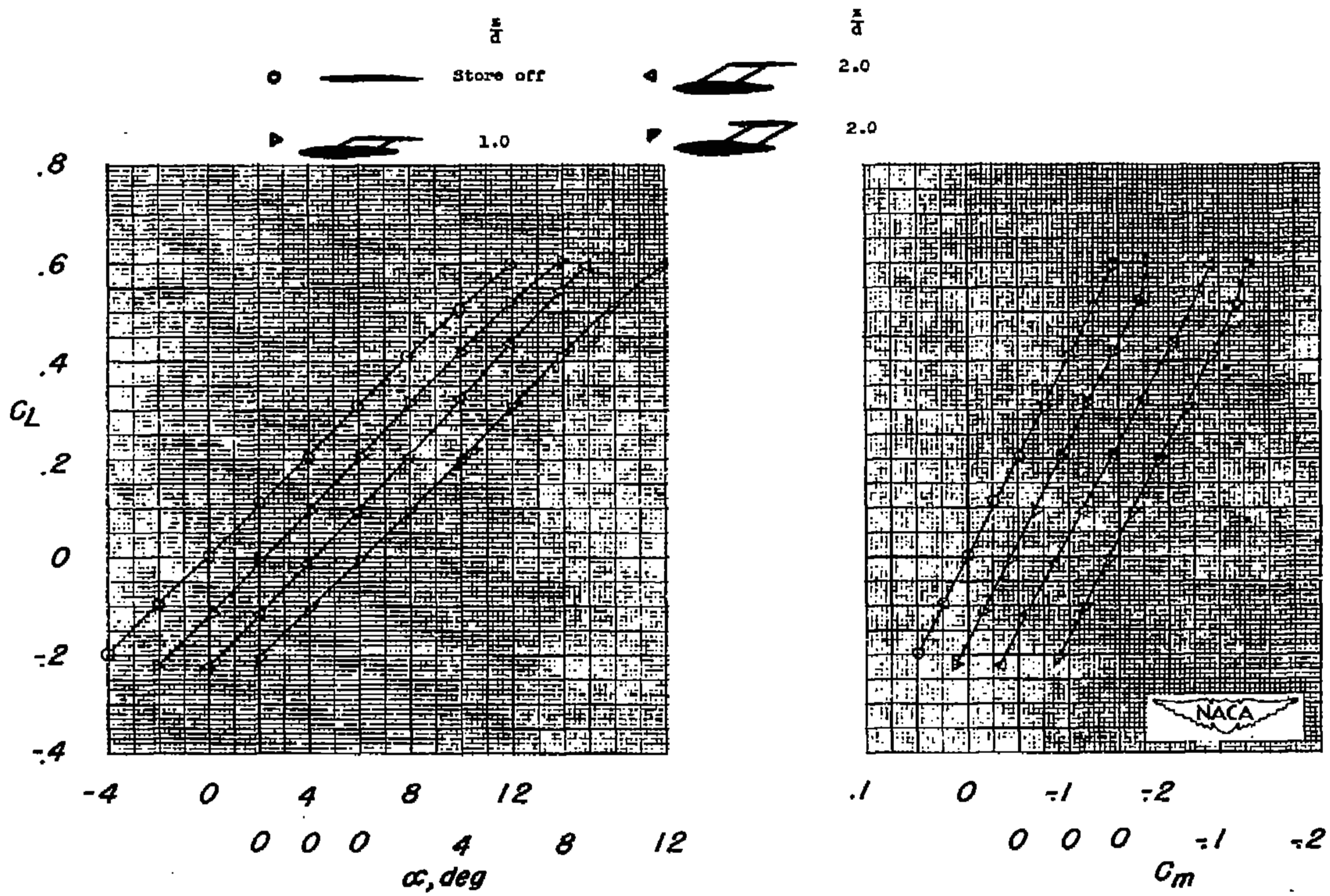
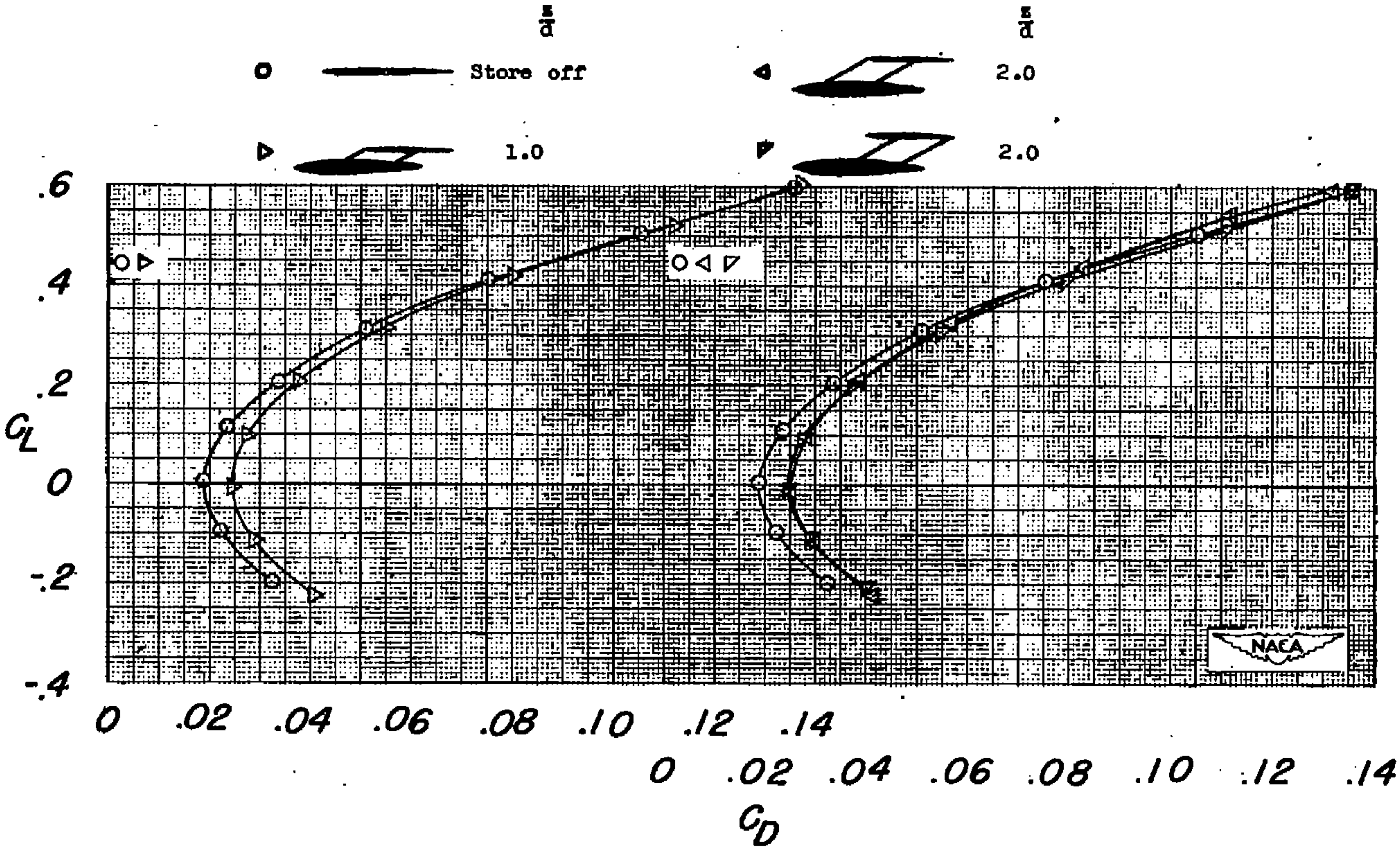


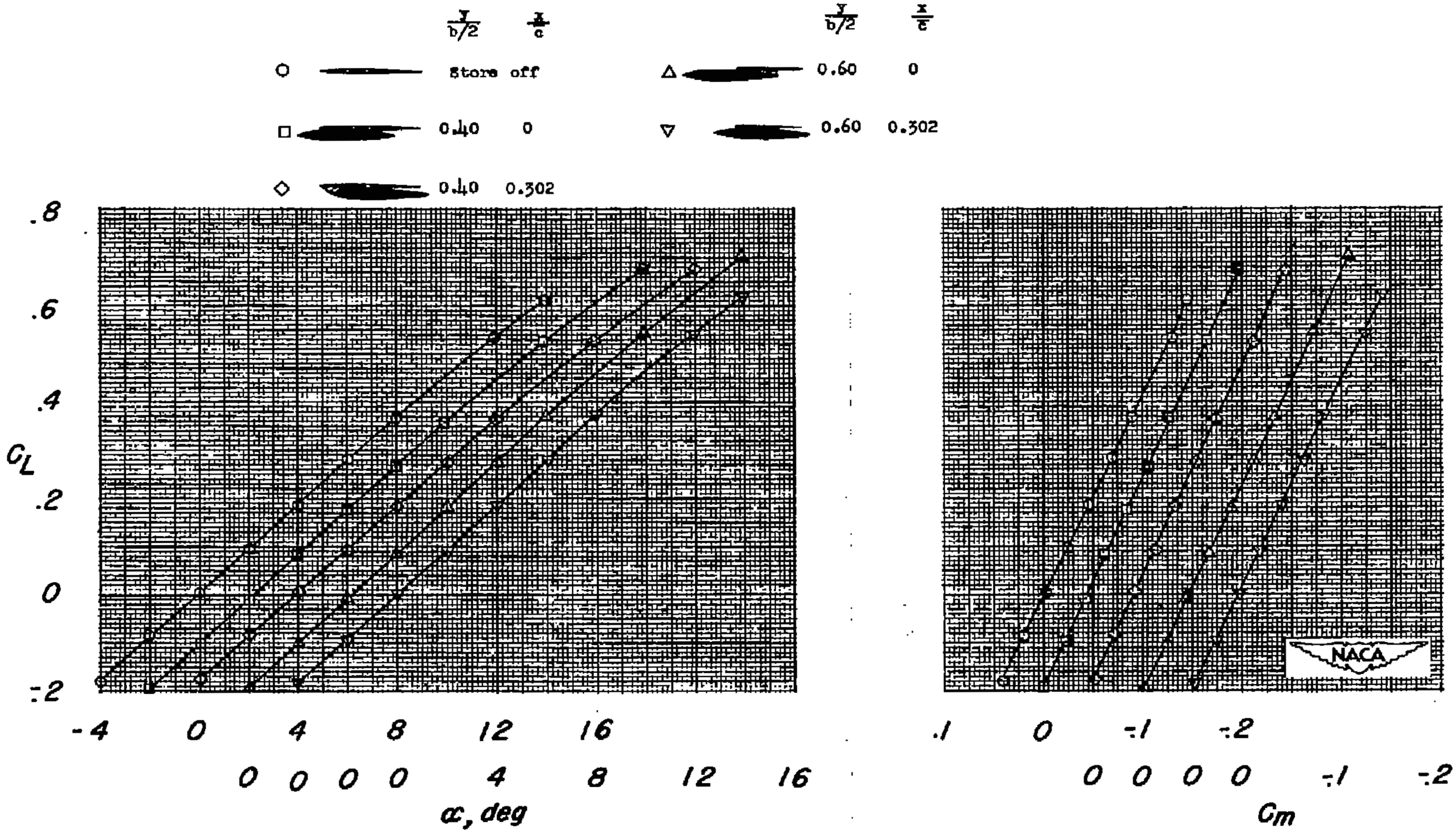
(a) C_L against C_m and α.

Figure 6.- Aerodynamic characteristics of the semispan model with DAC store attached to the wing by swept struts, one of which was set back. $M = 1.41$; $R \approx 2.8 \times 10^6$; $\frac{y}{b/2} = 0.60$; $\frac{x}{c} = 0$.



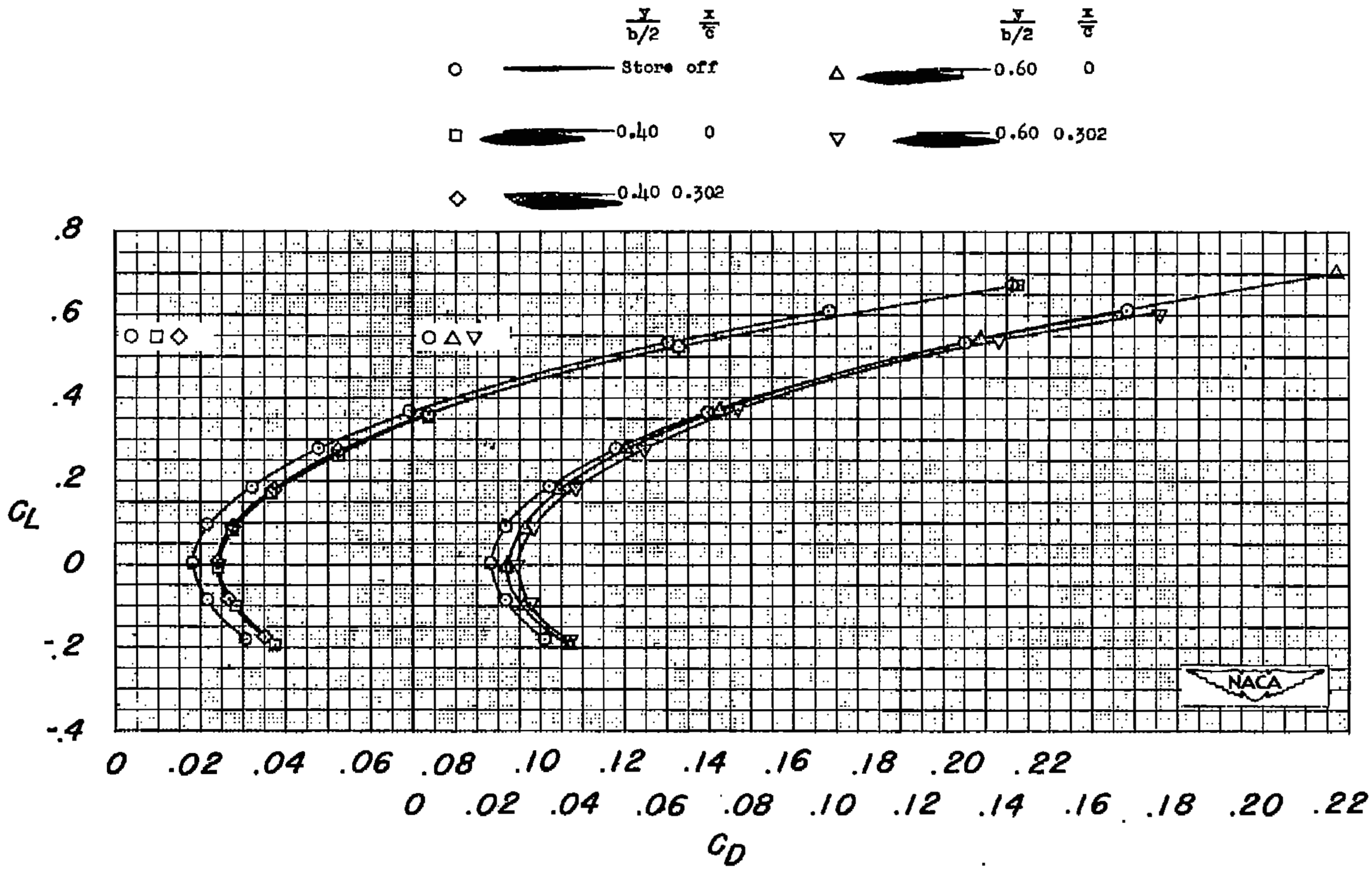
(b) C_L against C_D.

Figure 6.- Concluded.



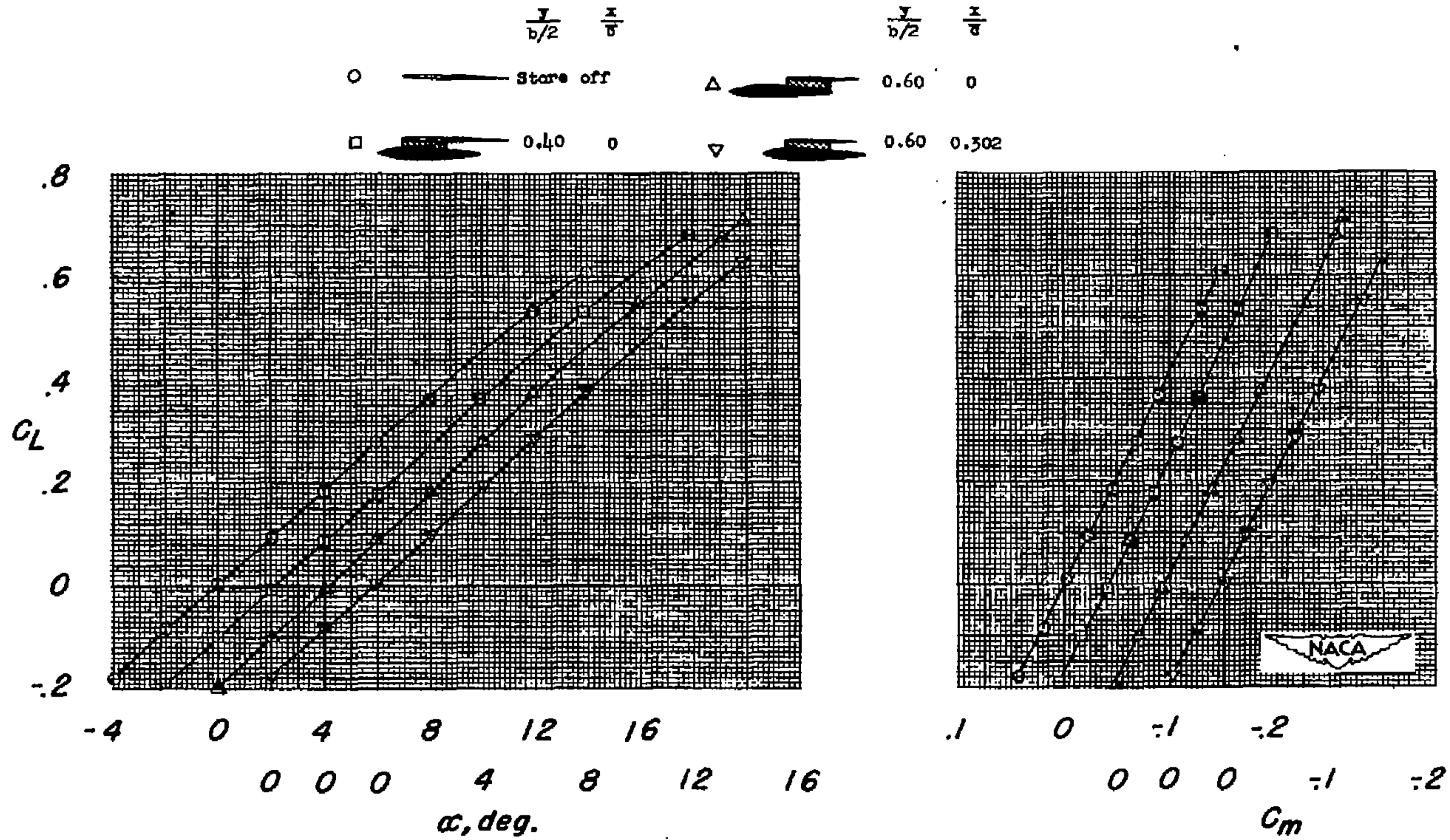
(a) C_L against C_m and α.

Figure 7.- Aerodynamic characteristics of the semispan model with DAC store at various chordwise and spanwise locations. $M = 1.62$; $R \approx 2.6 \times 10^6$; $\frac{z}{d} = 0.5$.



(b) C_L against C_D.

Figure 7.- Concluded.



(a) C_L against C_m and α.

Figure 8.- Aerodynamic characteristics of the semispan model with DAC store at various chordwise and spanwise locations. M = 1.62; $R \approx 2.6 \times 10^6$; $\frac{z}{d} = 1.0$.

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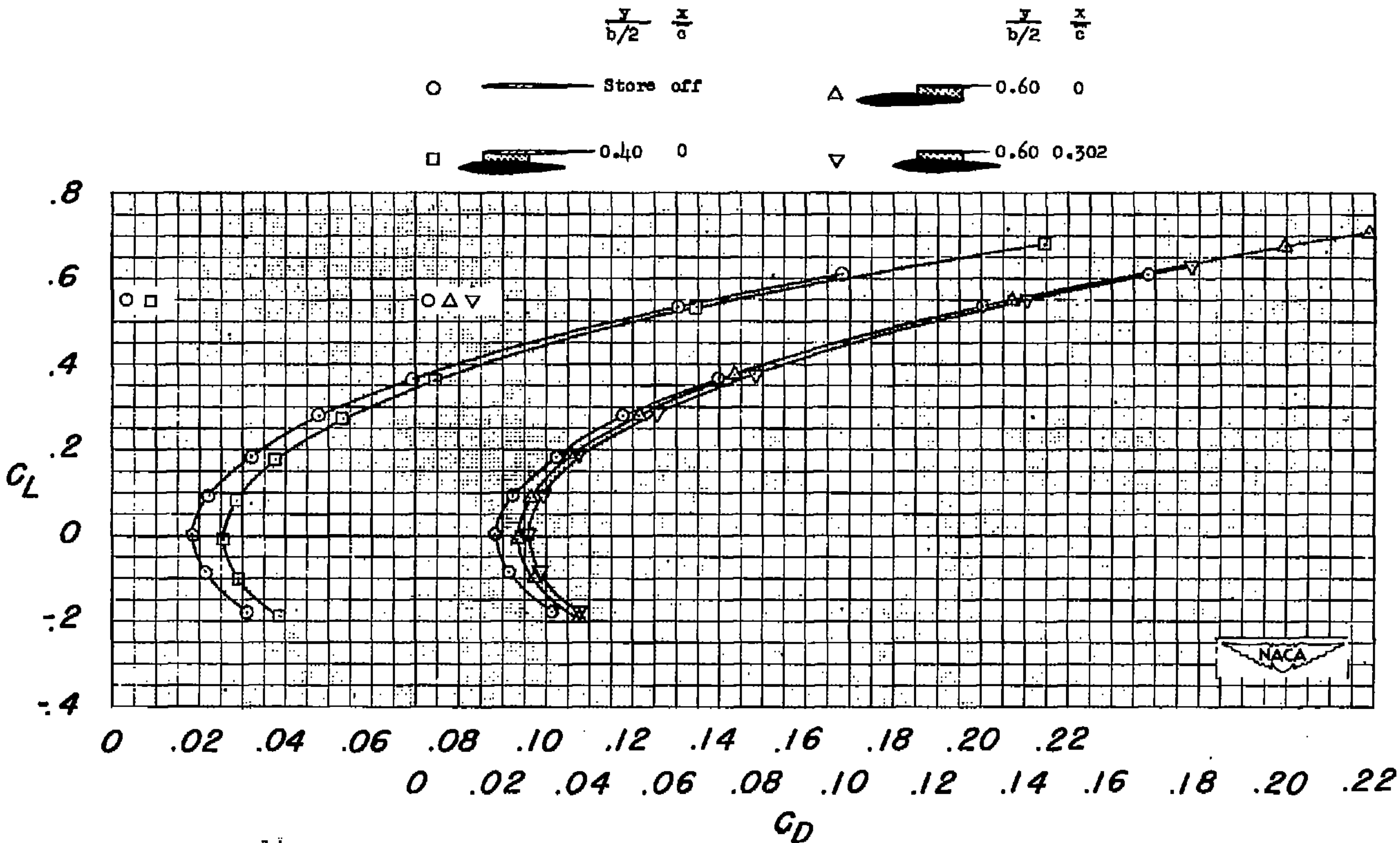

(b) C_L against C_D.

Figure 8.- Concluded.

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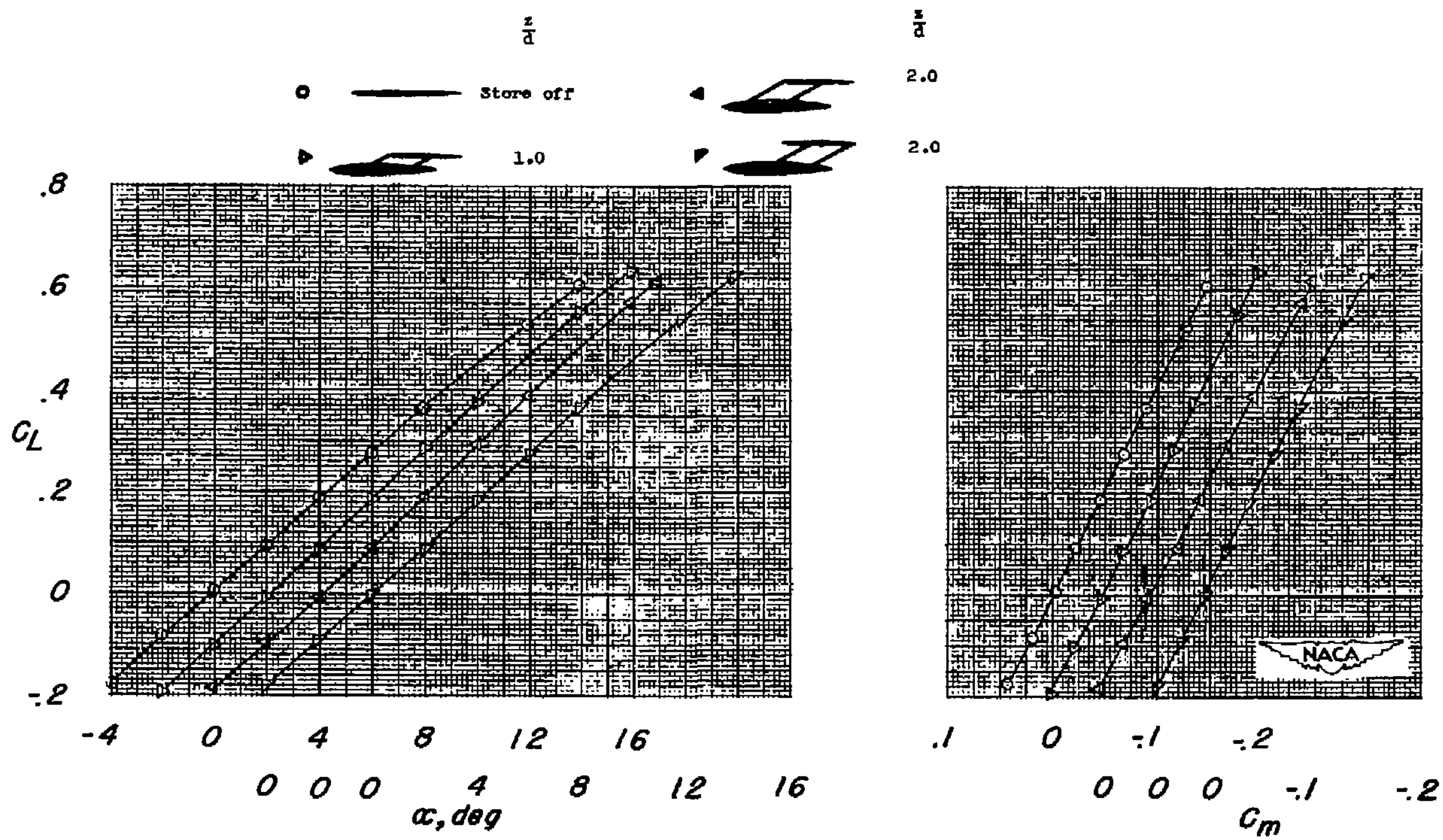

(a) C_L against C_m and α.

Figure 9.- Aerodynamic characteristics of the semispan model with DAC store attached to the wing by swept struts, one of which was set back. $M = 1.62$; $R \approx 2.6 \times 10^6$; $\frac{y}{b/2} = 0.60$; $\frac{x}{c} = 0$.

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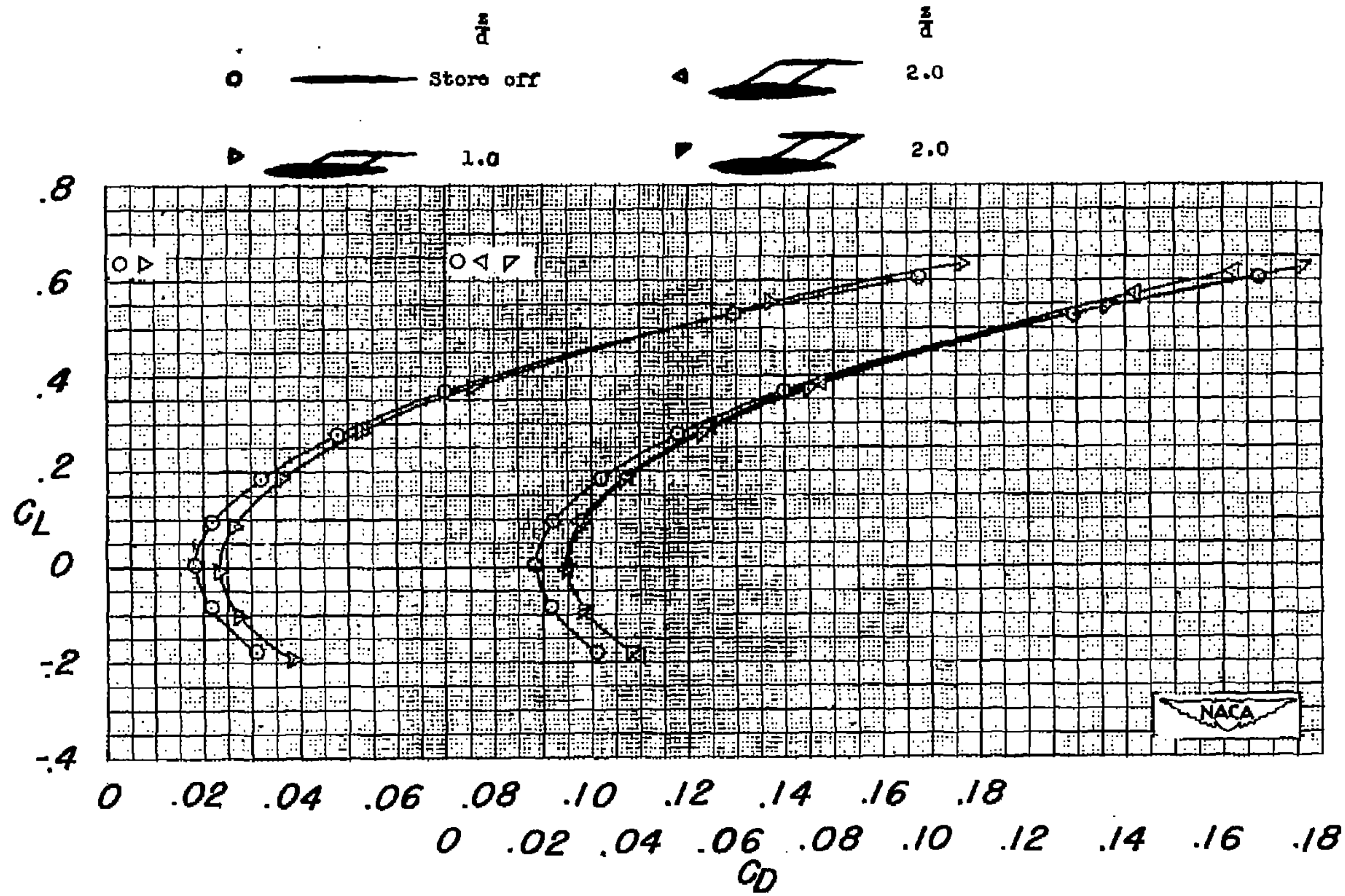

(b) C_L against C_D.

Figure 9.- Concluded.

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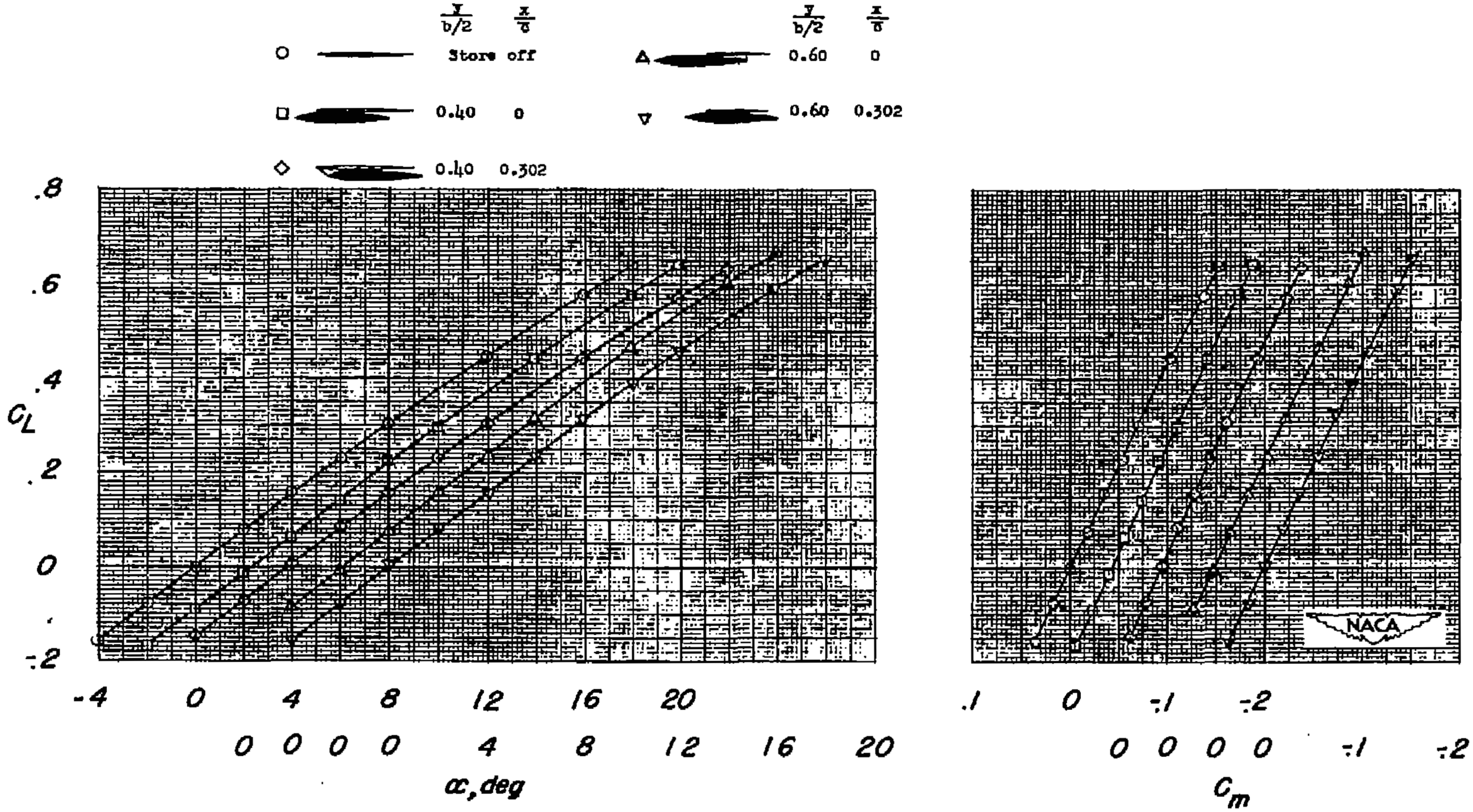

(a) C_L against C_m and α.

Figure 10.- Aerodynamic characteristics of the semispan model with DAC store at various chordwise and spanwise locations. $M = 1.96$; $R \approx 2.4 \times 10^6$; $\frac{z}{d} = 0.5$.

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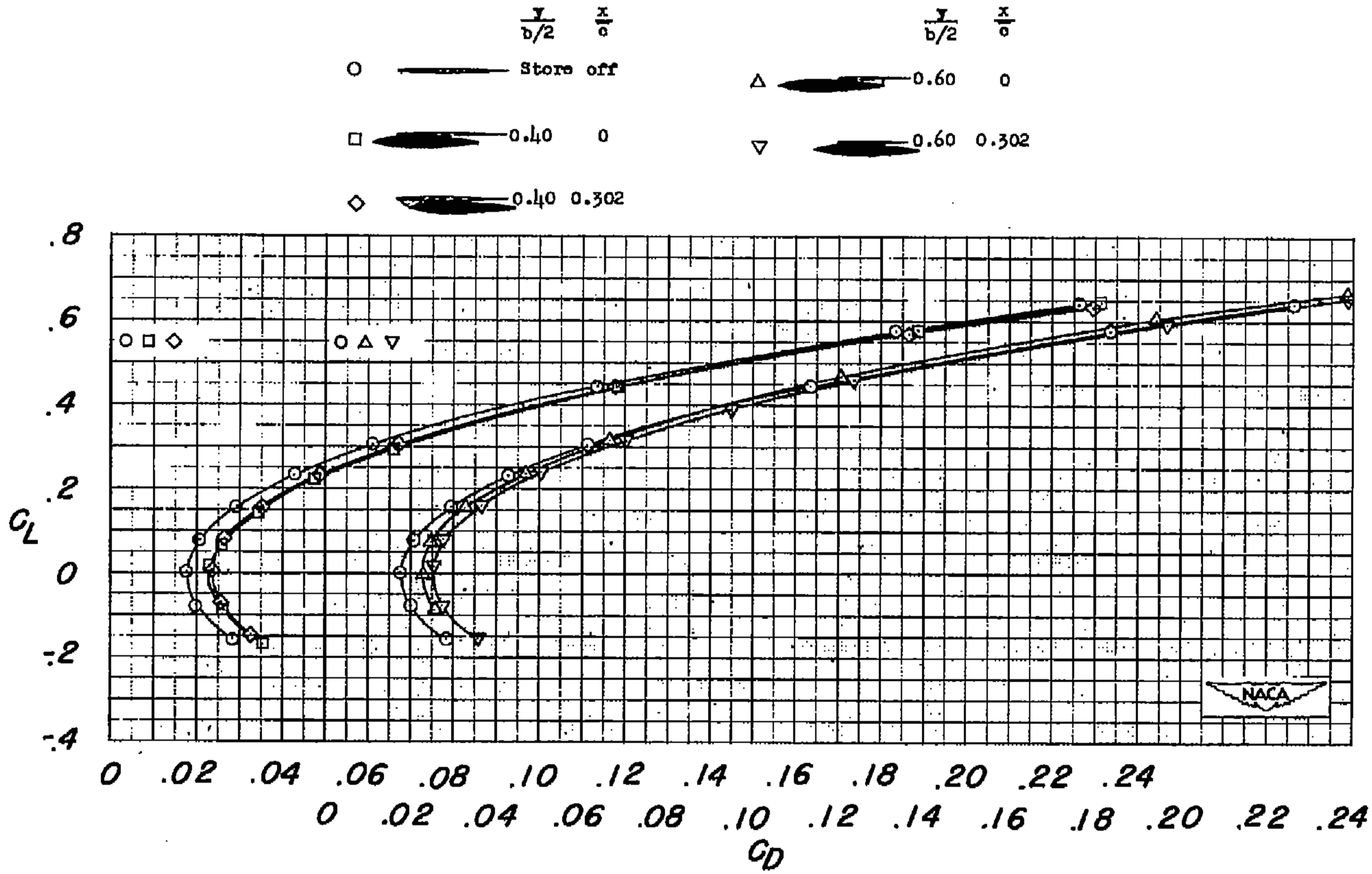

(b) C_L against C_D.

Figure 10.- Concluded.

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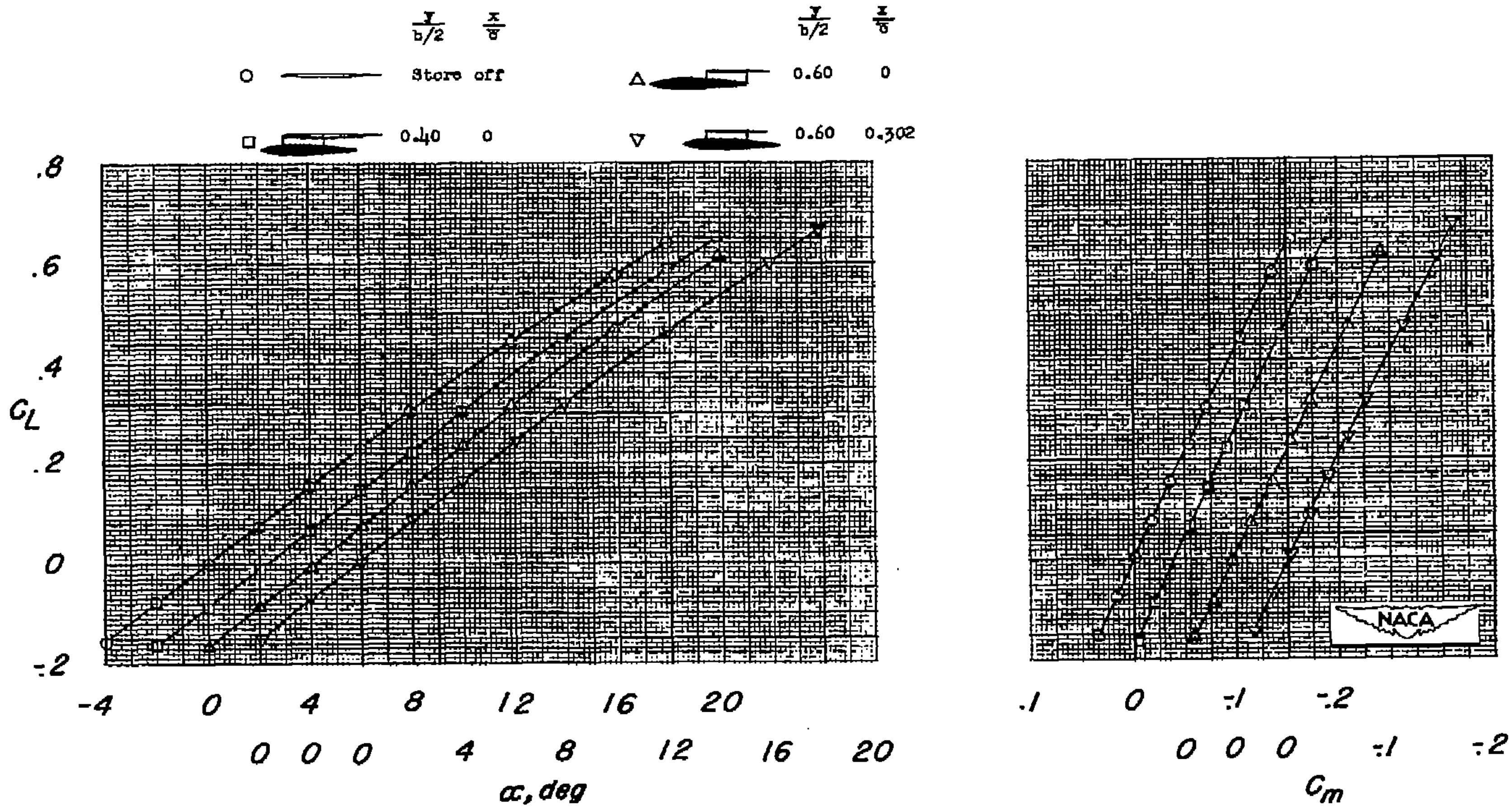
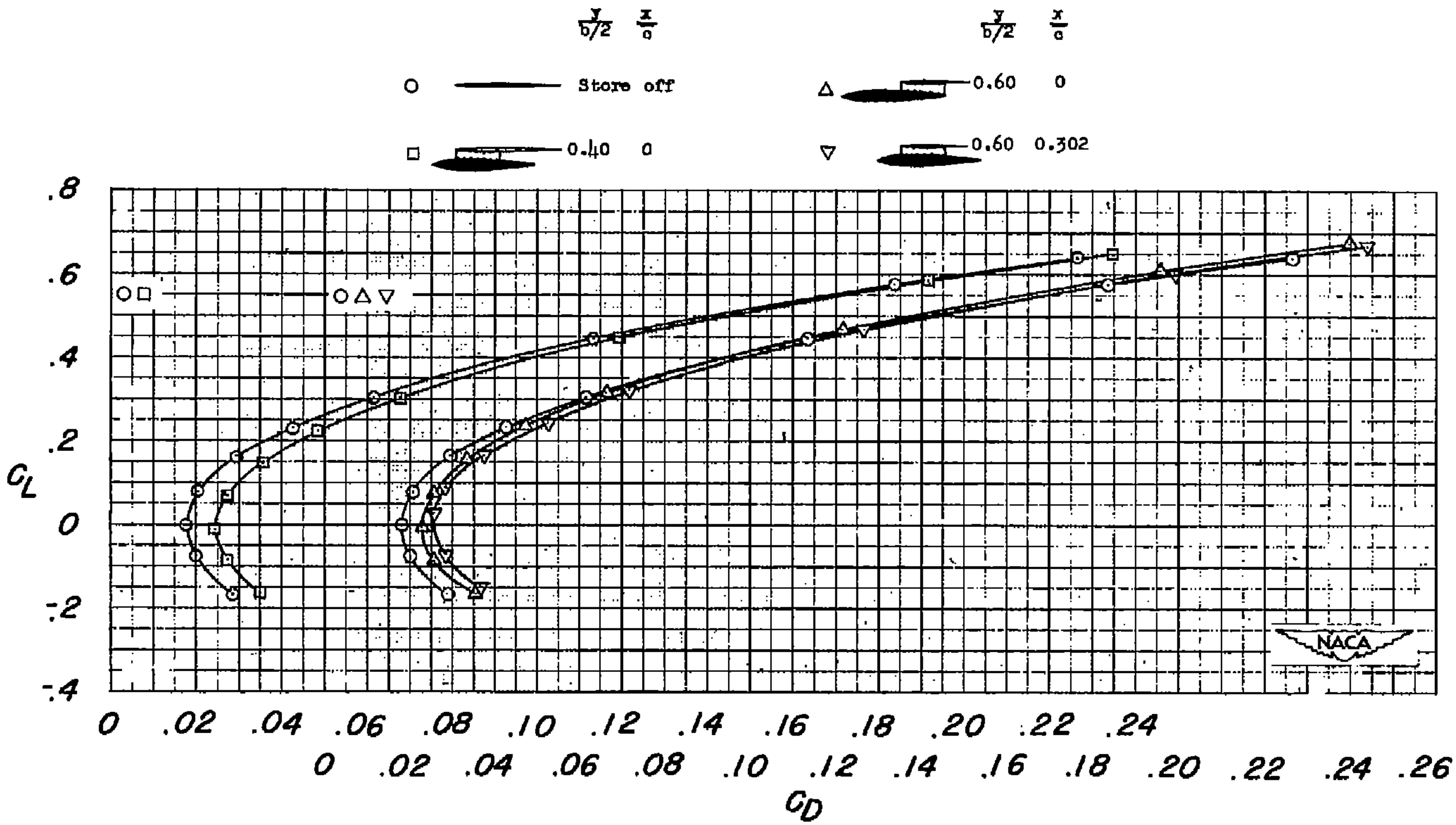


(a) C_L against C_m and α.

Figure 11.- Aerodynamic characteristics of the semispan model with DAC store at various chordwise and spanwise locations. $M = 1.96$; $R \approx 2.4 \times 10^6$; $\frac{z}{d} = 1.0$.

[redacted]

[redacted]



(b) C_L against C_D.

Figure 11.- Concluded.

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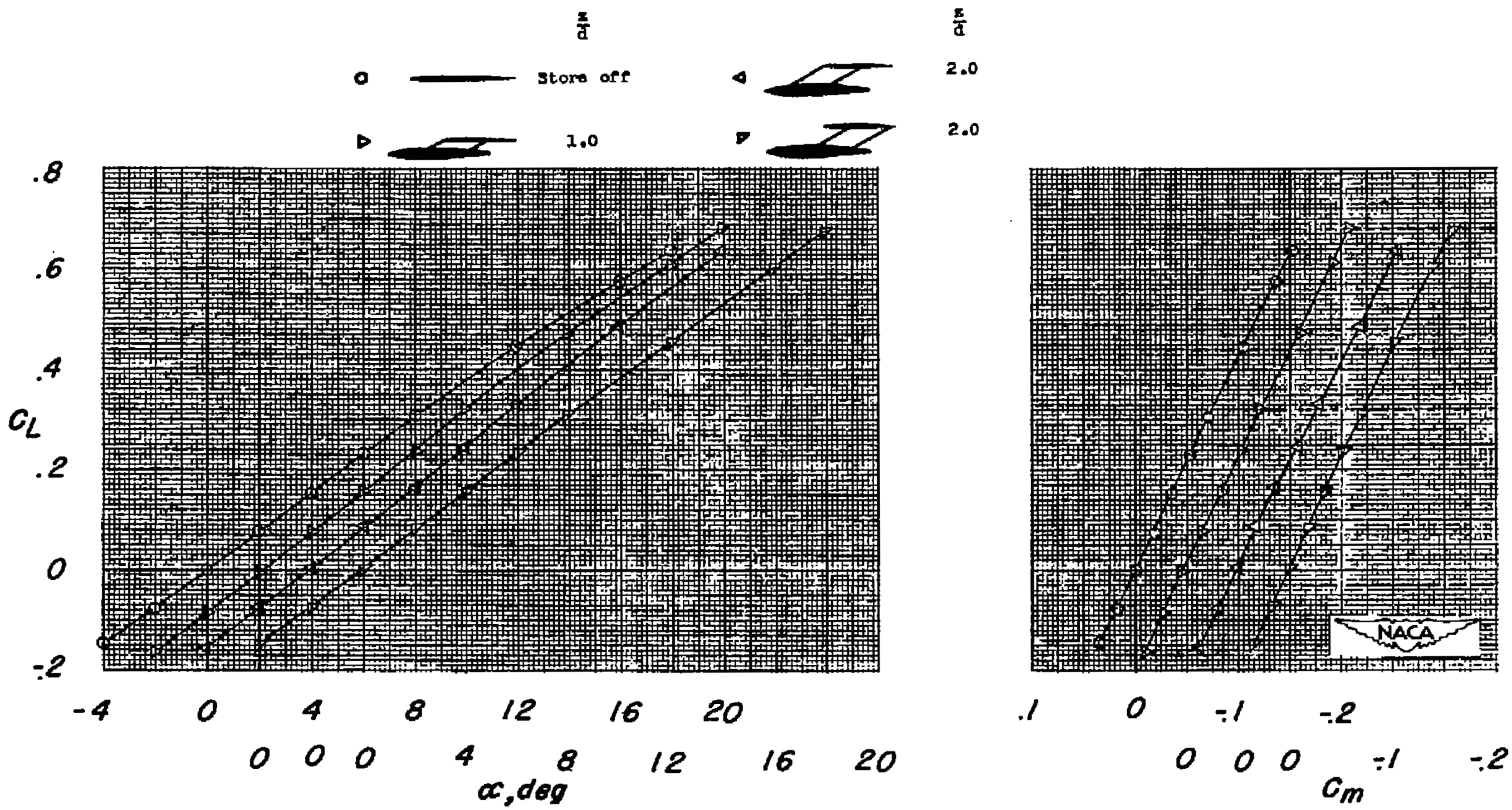

(a) C_L against C_m and α.

Figure 12.- Aerodynamic characteristics of the semispan model with DAC store attached to the wing by swept struts, one of which was set back. $M = 1.96$; $R \approx 2.4 \times 10^6$; $\frac{y}{b/2} = 0.60$; $\frac{x}{c} = 0$.

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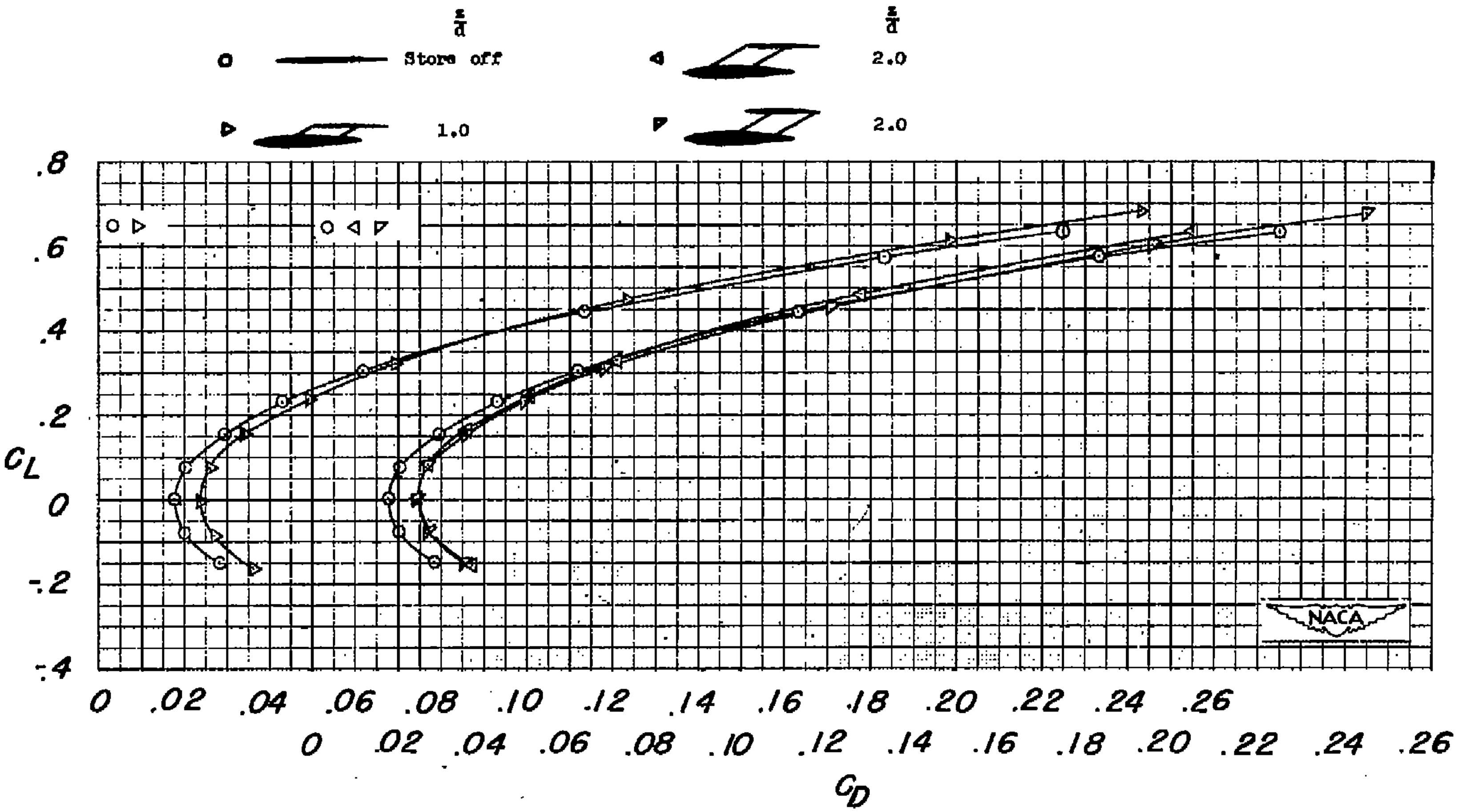

(b) C_L against C_D.

Figure 12.- Concluded.

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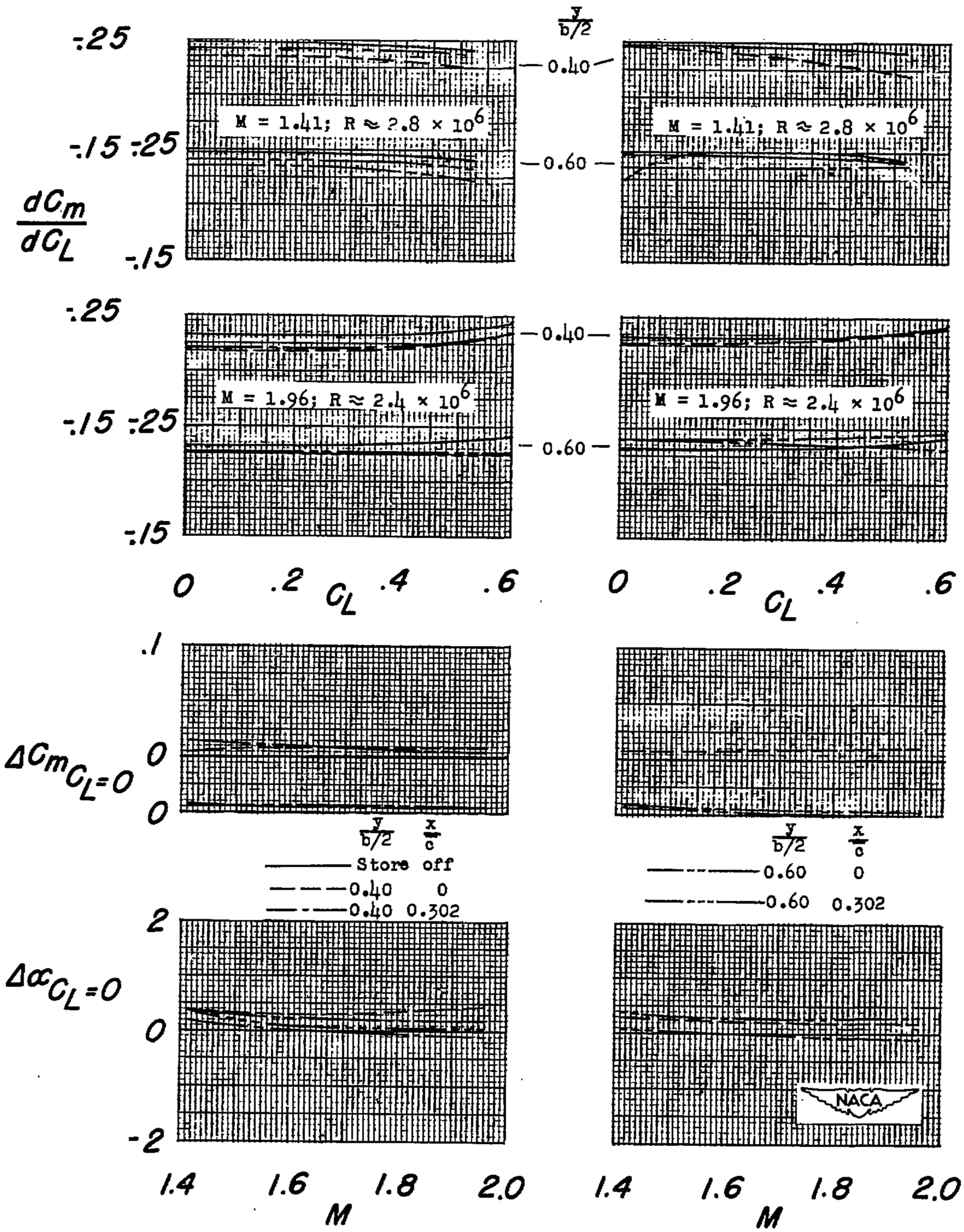
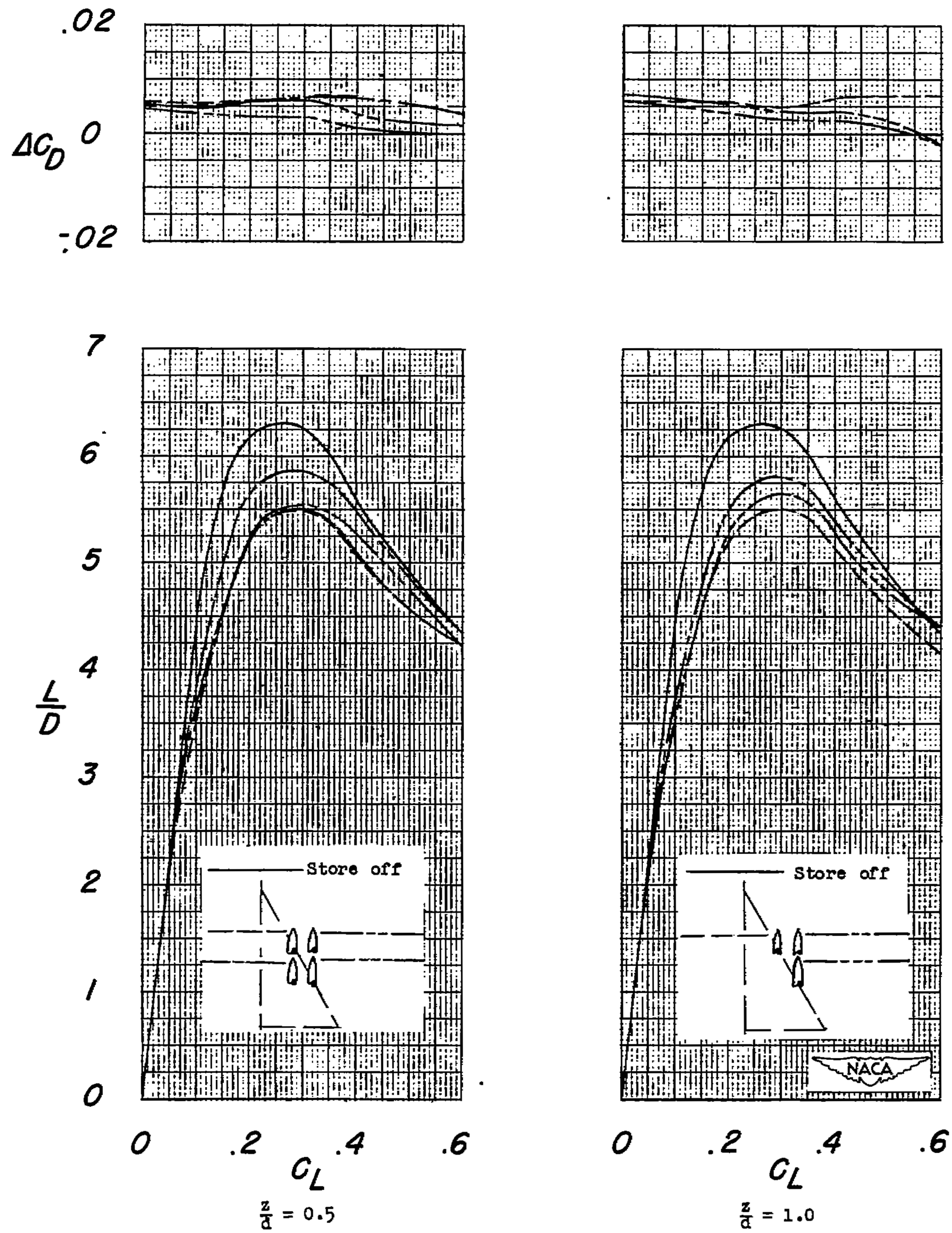


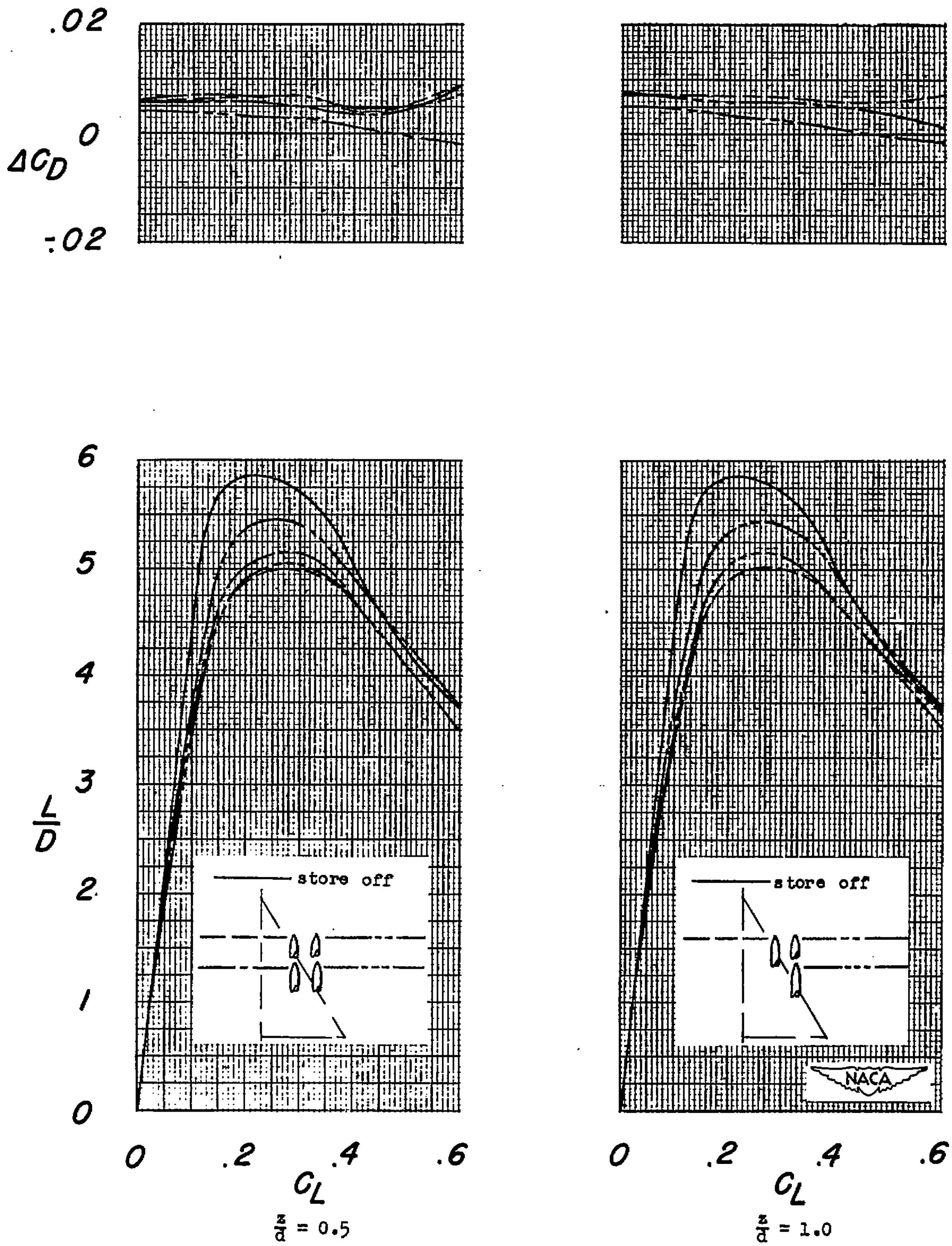
(a) $\frac{z}{d} = 0.5$. (b) $\frac{z}{d} = 1.0$.

Figure 13.- Effects of store on wing dC_m^*/dc_L, ΔC_m, and $\Delta\alpha$ at zero lift. DAC store.



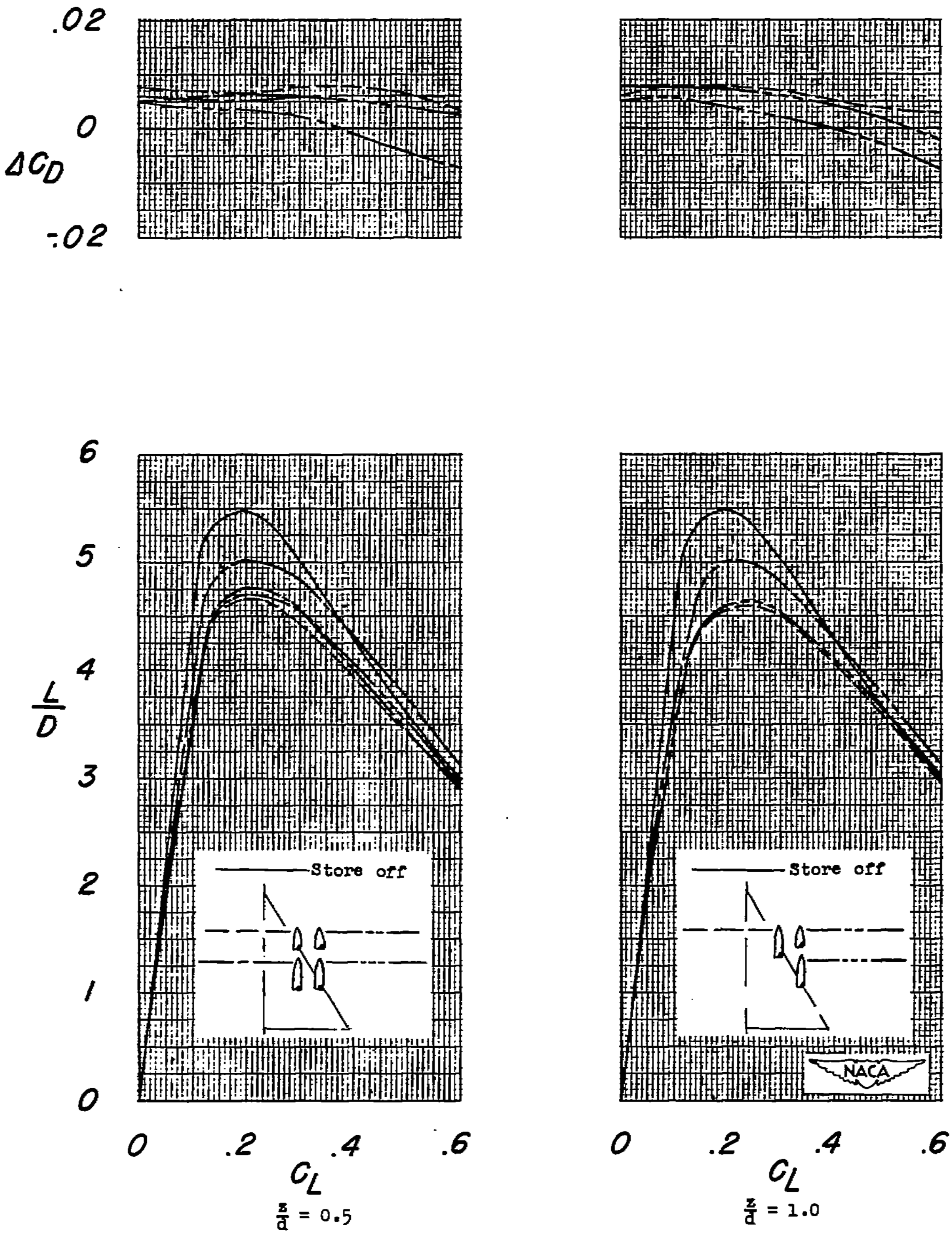
(a) $M = 1.41$; $R \approx 2.8 \times 10^6$.

Figure 14.- Variations of store incremental drag coefficient and lift-drag ratio with lift coefficient for various vertical, chordwise, spanwise locations of the DAC store on the semispan model.



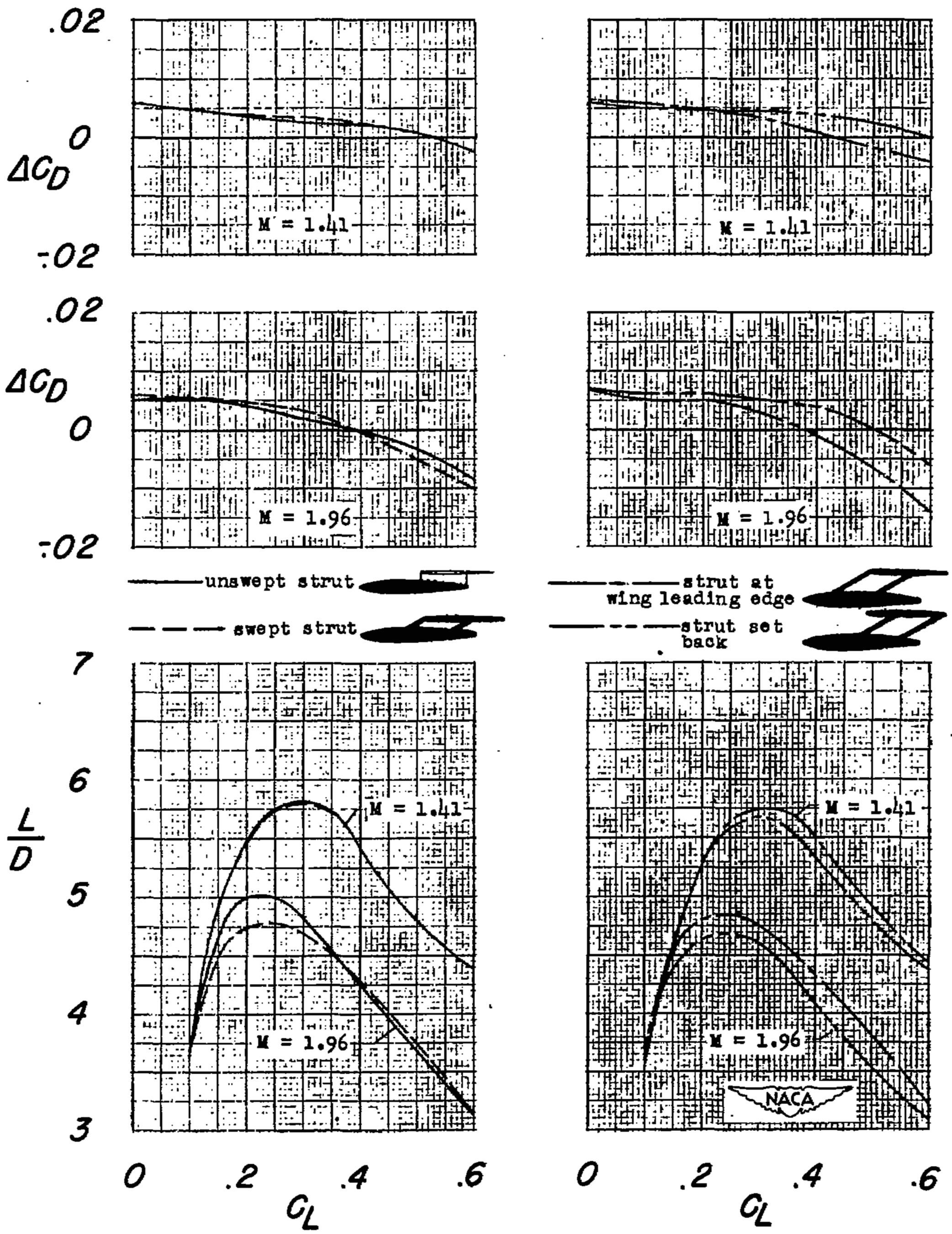
(b) $M = 1.62$; $R \approx 2.6 \times 10^6$.

Figure 14.- Continued.



(c) $M = 1.96$; $R \approx 2.4 \times 10^6$.

Figure 14.- Concluded.



(a) Effects of strut sweep; $\frac{z}{d}$ = 1.0.

(b) Effects of strut chordwise location; $\frac{z}{d}$ = 2.0.

Figure 15.- Effects of varying strut sweep angle and strut chordwise location on the store incremental drag coefficient and on the lift-drag ratio of a semispan model. All stores were located at $\frac{y}{b/2}$ = 0.60 and $\frac{x}{c}$ = 0.

SECURITY INFORMATION

[redacted]

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